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(56) Documents cited
GB 1459567
GB 1304405
GB 1293821
GB 1262664
GB 1090900
GB 949593
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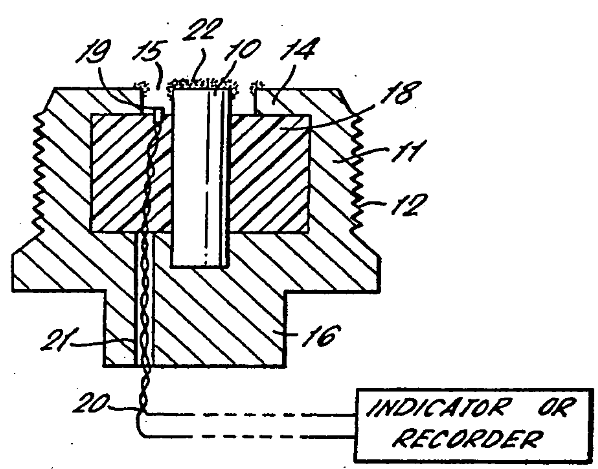
(54) Devices for detecting ferromagnetic particles in a liquid

(57) A magnetic device for attracting ferromagnetic particles in a liquid, such as a lubricating oil, is provided with sensor means to give an indication of the magnitude of the magnetic field in the region where the particles accumulate and hence an indication of the amount of accumulated material.

In one embodiment, shown in Figure 1, a Hall effect transducer 19 is located in a gap of a magnetic circuit comprising a permanent magnet 10 and a ferromagnetic body 11. The body is formed as a threaded plug for fitting in the sump of an I.C. engine so that ferromagnetic particles in the lubricating oil collect in and around the gap. The amount accumulated is shown by an indicator or recorder 23. In further embodiments Figures 2, 3 (not shown) a U-shaped magnet or a cylindrical bar magnet may be used.

FIG. 1.



Th drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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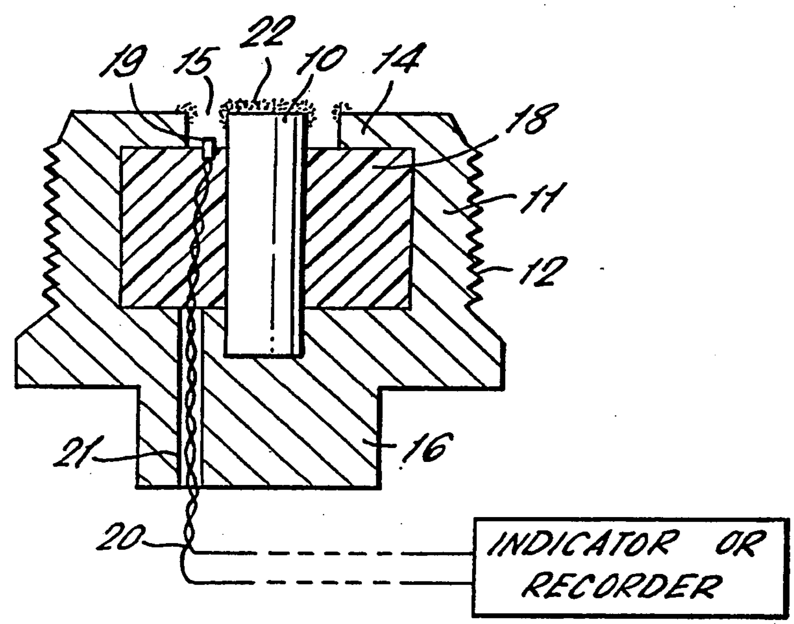
FIG. 1.



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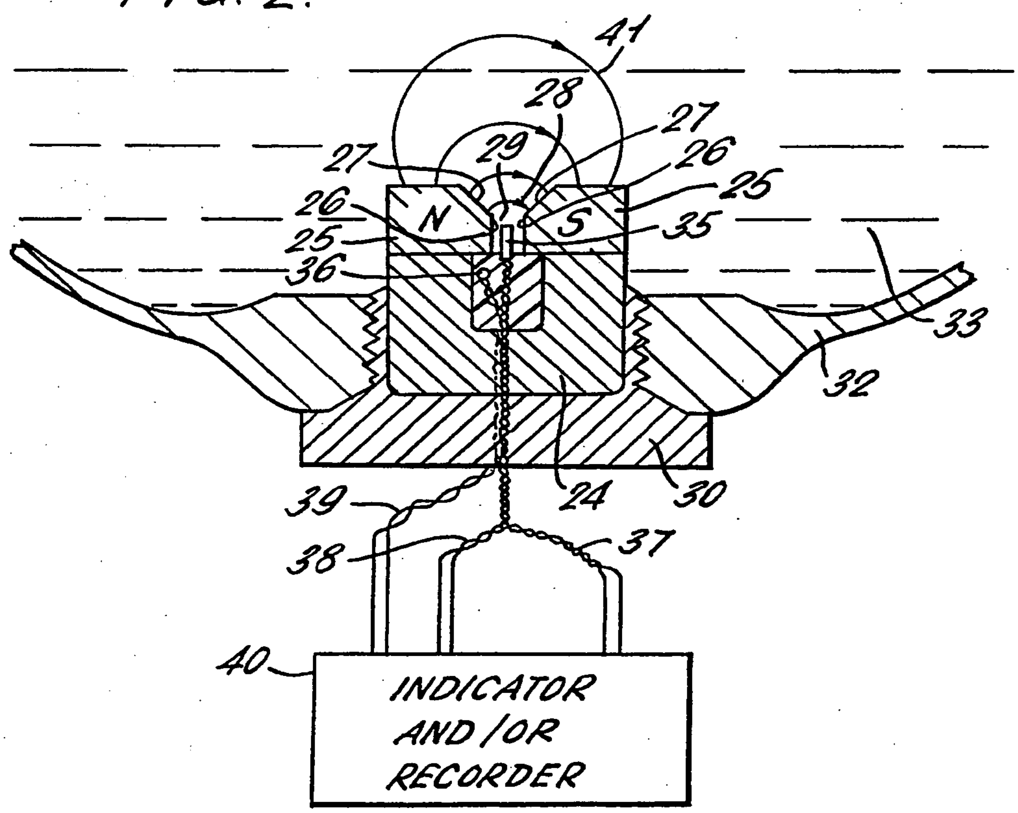
INDICATOR OR RECORDER

FIG. 2.



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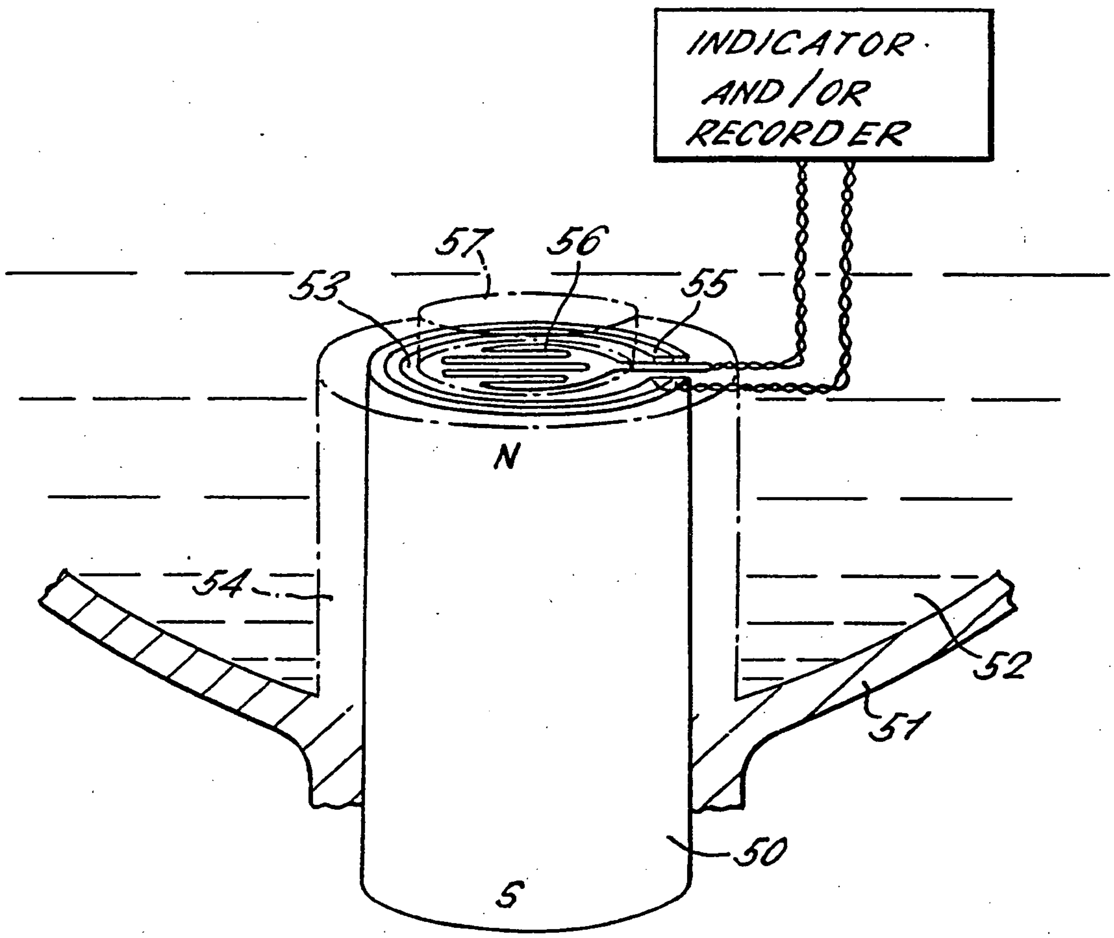
INDICATOR AND/OR RECORDER

FIG. 3.



SPECIFICATION

Improvements in or r lating t the collecti n of magnetic debris in lubricating il and other liquids

This invention relates to the collection of ferromagnetic particles in lubricating oil and other liquids.

It is well known to employ a magnetic plug for collecting ferromagnetic debris, for example in lubricating oils in internal combustion engines. One of the problems with such plugs however is that they are troublesome to inspect and there is no immediate quantitative display of the amount of debris or of the condition of the lubricating oil.

It has been proposed in Patent Specifications Nos. 1090900 and 1241204 to provide a bar magnet with one pole extending into the oil for collecting the debris from the oil and to provide a coil or coils for sensing the changes in magnetic field, due to accumulation of metal particles on the exposed pole of the magnet, by comparing the field due to this magnet with a reference field.

It is one of the objects of the present invention to provide an improved form of collector for ferromagnetic particles in a lubricating oil or other liquid which has a much higher sensitivity (i.e. magnetic field change per milligram of ferrous debris) than prior devices of the bar magnet type and hence makes it possible to measure or monitor the accumulation of magnetic debris in a practical environment with relatively inexpensive equipment.

According to this invention a magnetic device for attracting ferromagnetic particles in a lubricating oil or other liquid comprises magnet means including a magnetic circuit with at least one pole exposed to the liquid to attract the ferromagnetic particles and means responsive to the magnitude of the magnetic field in the region where the particles accumulate on said pole.

Inductive field measuring means effectively measure the slope of the B-H hysteresis loop (B being the magnetic flux density and H the magnetising field). We have found that the accumulated debris has a substantially greater effect on the magnitude of B than on the slope of the B-H curve. The use of a field magnitude sensing device, as distinct from an inductive sensor, thus improves the sensitivity.

In one form of the invention, a magnetic device for attracting ferromagnetic particles in a lubricating oil or other liquid comprises magnet means including a magnetic circuit with a gap between poles exposed to the liquid to attract the ferromagnetic particles therein and sensor means responsive to the magnitude of the magnetic field in or adjacent said gap to sense the accumulation of ferromagnetic particles on or adjacent the poles. The gap in the magnetic circuit will contain the liquid which will have a permeability substantially less than that of the magnet means and of the particles to be attracted. This perm ability will, in practice, be close to unity and, from the point of view of the magnetic circuit, can be considered as quivalent to an air gap. The sens r, in this form of the present invention, is put in or adjacent the gap betw en poles which are exposed to the liquid, and it is thus responsive not only to changes in the magnitude of the magnetic field due to debris accumulating but is also affected by displacement of the field due to the debris.

Ferromagnetic particles will be attracted to said pole pieces and will accumulate thereon. This causes changes in the reluctance of the magnetic circuit and also causes changes in the magnitude and position of the magnetic field in the gap or in the neighbourhood thereof. The sensing device is preferably located in the region where the magnetic field is concentrated by the accumulated debris so as to maximise the cumulative effect both of the increase in field and the change in position of the field.

The field responsive sensor means is conveniently a Hall effect transducer. Such a transducer can be made quite small and thus can readily be located in said gap or adjacent thereto. Alternatively a magneto-resistive sensing means may be employed.

The shaping of the magnetic system, particularly in the region of the poles, will have an effect on the way in which the accumulation of ferromagnetic debris builds up in the neighbourhood of the gap. The positioning of the sensor will also have an effect on the relationship between the sensor output and the accumulation of ferromagnetic debris. Thus by appropriate shaping and positioning of the components, a desired relationship between the range of change of sensor output and rate of accumulation of debris may be obtained.

The gap may be an annular gap between a central pole and a surrounding annular pole or it may be a gap between two similar poles, for example as in a "horseshoe" magnet. The gap shaping however is preferably such that the debris accumulates in the gap between the poles. A convenient arrangement is to have a pair of similar pole faces facing one another with said sensor means between the pole faces. The two pole faces, in this case, may be parallel to one another but, to attract the debris into the gap, it is convenient to make the gap wider where it is exposed to the source of debris, the gap narrowing to a region into which the collected debris accumulates.

Compared with a bar magnet having one pole exposed to a liquid, a magnet, such as a "horseshoe" magnet, having a gap provides better trapping of debris in the "near field" region, subject to the appropriate choice of the width and geometry of the gap. This property may be useful for trapping very fine debris, for example, having a dimension of a micron or less; such fine debris is commonly generated by normal wear processes. If the sensor is smaller than the trapping area of the magnet, and is located in the gap, this arrangement gives good uniformity of response to debris at different positions.

A conventional bar magnet, with a pole portion protruding into the liquid, has, compared with a magnet with a gap exposed to the liquid, superior d bris attracting properties at a distance. It tends to accumulate debris wh re there is the greatest non-uniformity f the field. In the case of a cylindrical bar magnet with flat end surfaces normal to the axis of the magnet, the debris collects at the periphery of

the end face and so will increase the flux at the periphery and reduce it at the centre of the end face. As explained above, the sensor is preferably put in the region where the debris collects and where there is maximum change of field strength, that is to say, around the periphery of the end face of a cylindrical bar magnet.

Thus the invention furthermore includes within its scope a magnetic device for attracting ferromagnetic particles in a lubricating oil or other liquid comprising a bar magnet having one end extending into the liquid to attract ferromagnetic particles therein, and means responsive to the magnitude of the magnetic field adjacent the peripheral portion of that end face of the magnet which is exposed to the liquid. If the magnet is a cylindrical bar magnet with an end face normal to the axis of the bar, the sensor is preferably of annular or part annular form for sensing the magnitude of the magnetic field in an annular region adjacent the peripheral part of that end face of the magnet which extends into the liquid.

Shields of non-magnetic material may be provided around the surfaces of the bar magnet where it extends into the liquid to shield parts thereof and thus to make the debris accumulate preferentially in the region of the sensor.

Indicator means may be provided for indicating the measured parameter, e.g. the field strength. The indicator, in many cases, need only indicate whether the sensed parameter is above or below a predetermined magnitude. It is possible however to indicate the magnitude of the sensed parameter. In some cases it may be desired to indicate the rate of change of the measured parameter so as to indicate the rate of accumulation of magnetic debris and, for this purpose, recording means may be provided for recording the measured parameter. For this purpose a data logger or digital recording system or chart recorder might for example be used.

The magnet means may include a permanent magnet. This avoids any necessity for an external electric power supply as would be necessary for an electromagnet. However for some purposes, it may be preferred to use an electromagnet; an electromagnet may be switched off to facilitate the removal of accumulated debris. After the magnet has been switched off, the debris around the pole faces may be removed for example mechanically or electrically.

The magnetic device may conveniently be formed as a removable plug for fitting into a liquid container. Typically the plug may be a threaded plug for screwing into the base of a liquid container such as the sump of an internal combustion engine or a pipe line through which a lubricant is pumped.

The following is a description of three embodiments of the invention, reference being made to the accompanying drawings in which:-

Figure 1 is a sectional elevation of a magnetic plug for fitting in the sump of an internal combustion engine;

Figure 2 is a sectional elevation of another construction of magnetic plug, showing part of the sump in which it is fitted; and

Figure 3 is a diagrammatic perspective view of another construction of magnetic plug also showing, in section, part of the sump into which the plug is fitted.

Referring to Figure 1 of the drawings, ther is shown a permanent magnet 10 of bar shape, the lower end of which fits closely in a surrounding ferromagnetic plug body 11 which is generally of cylindrical form with an external thread 12 for engaging a threaded bore in the sump of an internal combustion engine. This ferromagnetic body 11 has an inwardly-directed flange 14 at its upper end so leaving an annular gap 15 in the magnetic circuit around the top end of the bar magnet 10. The lower end of the plug body has a protruding portion 16 of square or hexagonal section for engagement by a spanner.

The plug body forms a magnetic circuit extending from the lower end of the magnet around to the top end leaving the aforementioned annular gap. The interior region between the plug body and the magnet is filled with non-magnetic material, for example an epoxy resin as shown at 18. A Hall effect transducer 19 is located by means of this resin in the gap 15 and has connecting leads 20 to provide energising current for the transducer and to carry the output voltage to an indicator or recorder 23; these leads extend through a bore 21 in the plug body.

In use the ferromagnetic particles accumulate around the top end of the magnet and the plug body adjacent the gap as shown at 22 and so change the location and magnitude of the magnetic field through the gap. This magnetic field is sensed by the Hall effect transducer to provide an output which is fed to the indicator and/or recorder 23.

Particularly when a Hall effect transducer is used, it may be desirable to provide some compensation for changes in the sensor output due to changes in temperature. For this purpose, a thermistor or other temperature sensitive device may be provided which is situated so as to be responsive to the temperature of the magnetic plug or of the fluid in contact therewith, this temperature sensitive device being arranged to provide an electric output compensating for the temperature changes in the sensor output.

In one convenient construction, a second Hall effect transducer is provided in a second gap in the magnetic circuit such that it is not affected by any accumulation of magnetic particles. The two transducers are connected in opposition. Such an arrangement, in addition to giving temperature compensation gives increased sensitivity.

A magneto resistive sensor may be used instead of a Hall effect device. Particularly with magneto-resistive devices, field and temperature compensation is desirable and therefore a pair of devices may be electrically coupled differentially, one of the devices being in the field to be sensed and the other being preferably in a region where the field is not affected by accumulating debris but at least is differently affected by the d bris.

Many variations in th physical construction are possible. It may be convenient in some cases to use a horsesh e-shaped magnet which may be mounted for example in a plug body or non-magnetic material. In other cases it may be preferred to use an electromagnet which can be switched off when it is

required to remove debris from the neighbourhood of the pole faces.

If a permanent magnet is employed, electrically energised means, e.g. an electro-magnet may be provided to reduce the field in the gap for the purpose of removing accumulated particles.

Figure 2 illustrates another form of construction with a U-shaped ("horseshoe") permanent magnet 24 having two inwardly facing pole pieces 25, the pole faces having parallel portions 26 and sloping portions 27, the latter forming a wedge-shaped gap 28 guiding debris downwardly and inwardly into the narrower gap 29 between the parallel portions of the faces. The magnet 24 is mounted in a non-magnetic body 30 having a threaded portion 31 for screwing into the base 32 of a sump 33 for lubricating oil. A magnetic field sensor, in this embodiment a Hall device 35, is provided in the magnetic gap 29 where the debris accumulates. A temperature compensating device, in this case a thermistor 36, is provided adjacent the magnet pole pieces 25. The voltage leads 37 and control current leads 38 and the thermistor leads 39 extend to an indicator and/or recorder 40 for indicating and/or recording the magnitude of the magnetic field in the gap 29. This field depends on the accumulation of ferromagnetic debris in the gap and hence gives a measure of amount of debris that has been attracted to and accumulated on the plug.

With a magnetic system as shown in Figure 2, having a narrow gap between the pole faces, the strong parts of the magnetic field lie close to the poles, as indicated by the lines 41 indicating the field. This type of device therefore is particularly advantageous for attracting fine particles of ferromagnetic material which are relatively close to the magnet.

A bar magnet with one end extending into the liquid has superior debris-attracting properties compared with the devices of Figures 1 and 2. Part of a plug incorporating such a bar magnet is shown in Figure 3. In this particular embodiment a cylindrical permanent magnet 50 is secured (by means not shown but typically a threaded holder) in the base 51 of a sump 52 for lubricating oil. The magnet has a flat upper pole face 53 in a plane normal to the axis of magnet. The debris preferentially collects around the peripheral portion of this face 53, that being the region where there is the greatest non-uniformity of the field. Further to ensure that the debris collects in this region, the cylindrical surface of the magnet 50 within the sump is shielded by a non-magnetic guard 54, for example a thick layer of plastics material. A magneto-resistive sensor 55 extends almost completely around an annular portion of the pole face 53 near the peripheral edge thereof. For temperature and field compensation, a second magneto-resistive sensor 56, in this case of digitated form, is provided in the central region of the face 53 but is covered by a non-magnetic guard 57. The guard shields 54 and 57 are each of such thickness that ferromagnetic particles are preferentially attracted to the peripheral region of pole face 53, where the magnetic field is stronger than at the surface of the guard shields. The two magneto-resistive devices 55, 56 are connected to an indicator and/or recorder 58, in which, electrically, the outputs of the two sensors are differentially combined to give the required temperature compensation, as giving an output, which changes in accordance with changes in the magnetic field in the peripheral region of the pole face.

By the construction of Figure 3, the advantages of the bar magnet for attracting particles from a distance are obtained whilst still retaining a high sensitivity by sensing the magnitude of the field in a limited region of the pole face onto which the particles are preferentially attracted.

In all the embodiments described, it is possible to provide indicator means, e.g. an indicator lamp, to give a warning when the measurement parameter has exceeded a predetermined magnitude.

A plug such as has been described above may be incorporated in oil feed or return pipes of a lubrication system for example to monitor the quality of the oil being passed to or from a bearing or the like. In such arrangements in which the oil is flowing along a predetermined path, centrifugal or inertial effects may be utilised to help separate the particles in the oil from the liquid and to direct such particles towards the magnetic plug. Furthermore additional magnets, for example powerful permanent magnets, may be provided to attract the ferromagnetic particles towards the magnetic plug used for sensing the amount of accumulated debris.

Particles which have been collected in the plug may be removed periodically, e.g. by a mechanical wiper. In one construction, the magnet is rotated past a wiper periodically to remove all or substantially all the accumulated debris. If the rate of accumulation of particles is to be measured, the magnet may be rotated continuously.

CLAIMS

1. A magnetic device for attracting ferromagnetic particles in a lubricating oil or other liquid comprising magnet means with at least one pole exposed to the liquid to attract ferromagnetic particles and sensor means responsive to the magnitude of the magnetic field in the region where the particles accumulate on said pole.

2. A magnetic device for attracting ferromagnetic particles in a lubricating oil or other liquid comprising magnet means including a magnet circuit with a gap between poles exposed to the liquid to attract ferromagnetic particles therein and sensor means responsive to the magnitude of the magnetic field in or adjacent said gap to sense the accumulation of ferromagnetic particles on or adjacent the poles.

3. A magnetic device as claimed in claim 2 wherein said gap is an annular gap between a central pole and a surrounding annular pole.

4. A magnetic device as claimed in claim 2 wh rein said gap is a gap between two similar poles.

5. A magnetic device as claimed in claim 4 wherein said gap is formed by a pair of similar pole faces facing one another with said sensor means between them.

6. A magnetic device as claimed in claim 5

wherein the pole faces have parallel portions facing one another, together with sloping portions defining a wedge-shaped gap for guiding debris into the narrower portion of the gap between said parallel portions.

7. A magnetic device as claimed in any of the preceding claims wherein said sensor means comprises a magneto-resistive device.

8. A magnetic device as claimed in claim 7 wherein a second magneto-resistive device is provided for temperature compensation, the two devices being differentially connected electrically.

9. A magnetic device as claimed in any of claims 1 to 6 wherein said sensor means is a Hall effect transducer.

10. A magnetic device as claimed in claim 9 wherein temperature sensitive means are provided operative to compensate the output of the sensor means for changes in temperature of said Hall effect transducer.

11. A magnetic device as claimed in claim 10 wherein the temperature-sensitive means comprise a thermistor.

12. A magnetic device as claimed in claim 10 wherein the temperature-sensitive means comprise a further Hall effect transducer.

13. A magnetic device as claimed in claim 2 wherein said sensor means comprises a first Hall effect transducer located in or adjacent said gap and wherein a second Hall effect transducer is provided in another gap in the magnetic circuit unaffected by accumulating particles, the two transducers being arranged to give a differential output.

14. A magnetic device for attracting ferromagnetic particles in a lubricating oil or other liquid comprising a bar magnet having one end extending into the liquid to attract ferromagnetic particles therein, and means responsive to the magnitude of the magnetic field adjacent the peripheral portion of that end face of the magnet which is exposed to the liquid.

15. A magnetic device as claimed in claim 14 wherein the magnet is a cylindrical bar magnet with an end face normal to the axis of the bar and wherein the sensor is of annular or part annular form for sensing the magnitude of the magnetic field in an annular region adjacent the peripheral part of that end face of the magnet which extends into the liquid.

16. A magnetic device as claimed in either claim 14 or claim 15 wherein non-magnetic material is provided around the part of the magnet extending into the liquid leaving the end face or at least the peripheral part of the end face exposed.

17. A magnetic device as claimed in any of claims 14 to 16 wherein the means responsive to the magnetic field comprises an annular or part annular magneto-resistive sensor.

18. A magnetic device as claimed in claim 17 wherein a compensating magneto-resistive device is provided adjacent the central part of said end face.

19. A magnetic device as claimed in claim 18 wherein said compensating magneto-resistive devic has barrier means over it to prevent debris accumulating thereon.

20. A magnetic device as claimed in any of the preceding claims and having an indicator arranged to indicate the magnitude of a parameter sensed by said sensor means.

21. A magnetic device as claimed in any of th preceding claims and having recording means arranged to record the magnitude of a parameter sensed by said sensor means.

22. A magnetic device as claimed in any of the preceding claims wherein said magnet is a permanent magnet.

23. A magnetic device as claimed in claim 22 wherein electrically energised means are provided for reducing the magnetic field in said gap when accumulated particles are to be removed.

24. A magnetic device as claimed in any of claims 1 to 21 wherein said magnet is an electromagnet.

25. A magnetic device as claimed in any of the preceding claims and arranged as a removable plug for fitting into a liquid container.

26. A magnetic device as claimed in claim 25 and arranged as a threaded plug for a liquid container.

27. A magnetic device substantially as hereinbefore described with reference to Figure 1 or Figure 2 or Figure 3 of the accompanying drawings.

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